

Soil Environmental Studies with Application of Space Technology Advances and Geotechnical Investigations

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Abstract

An investigation of soil contamination is a very important issue in soil environmental studies. It leads to classification of all living organisms in the soil, as well as essential materials and particles that these organisms use to survive which together form the soil ecosystem. It is vital to study the soil ecosystem to understand interface and relationship of organisms existing in the soil and their impact to environment surrounding them.

Soil environmental study attracts an interest of scientists as one of the main factors of human live safety aspect. It is necessary to find out the way of combining of practical analysis and interpretation of soil surface information with further classification of environmental factors.

Geotechnical investigations are useful instruments in soil quality studies. They are based on the field measurements, soil, and groundwater sampling directly from studied area. The samples are then analyzed in laboratories with appropriate equipment and chemical substances to determine their mineral composition, physical and mechanical properties, and extents of pollution.

Remote Sensing method and Geographical Information Systems (GIS) represent the technology where geospatial data can be represented in the graphic form integrated into the geotechnical, geological and hydrological information routinely used by geotechnical engineers. Remote Sensing and GIS make available wide forms of spatial data to be integrated, selected, and sorted with any number of physical, chemical, or any possible environmental factors accessed by geotechnical measurements.

There are number of existing traditional methods for soil environmental studies. It is extremely important to use advances of technology for daily human social and public needs maintaining and satisfactions.

Undoubtedly, geotechnical investigations integrated into the space technology data open a large range of applications for solving of soil environmental problems.

Keywords

Geotechnical Investigations; Environment; Tests; Remote Sensing and GIS

Introduction

There is no doubt that Remote Sensing method is the instrument for development of GIS. It is obvious that GIS technology developments need collection of initial data based on aero and space information as well as field data collected by means of geotechnical measurements. A Remotely Sensed information required for GIS technology applications needed to be processed depending of kind of problem necessary to be solved.

Major areas of space science and technology applications in study of soil are following:

- Geotechnical investigation;
- Foundations;
- Earthquake;
- Landslide Studies;
- Application of Remote Sensing & GIS;
- Geological & Geophysical Investigation;
- Industrial Waste & Contaminated Soil.
- Some of the important infrastructures in geotechnical investigations can be classified as [1]:
- Total station for surveying & monitoring;
- Sub-surface profiling by Engineering Seismograph, Resistivity meter and Georadar;
- Mobile drilling rig for soil and rock exploration;
- Laboratory & field testing facilities for soil;
- Petrological microscope;
- Computer controlled Triaxial and consolidation Testing System;
- Computer controlled Laser Particle Size Analyzer;
- Geotechnical instrumentation for performance evaluation;
- Foundation Pile Diagnostic System;
- Strong Motion instruments;
- Digital Image Processing and Geographical Information System;

Geotechnical Data as an Indicator for Environmental Studies

An impact of soil contamination can play significant role in its use as an indicator in environmental soil studies. Application of geotechnical methods in environmental studies is one of the possibilities in monitoring of the processes especially in modification of indicators, which allows us to identify the reason and consequences of environmental impacts. The best way in applying of such indicators is evaluation of the benefits for the land, stabilization, improvement of the soil quality, creation a better area for sustainable biodiversity (flora and fauna), and improvement of the sustainable character for the future use. Subsequently, it leads to understanding of a picture of influence of the possible negative consequences including economic issues.

Undoubtedly, all indicators in environmental investigation need to be accurately identified in the beginning stage of measurement. It is necessary to consider such features of the selected area as feature of existing flora and fauna as well as soil condition. It makes possibility of selecting segments for sampling and measurements and manage successfully all the stages of investigation processes.

There is one more advantage to use of remote sensing methods and GIS technology applications, which is availability of integration of all data collected from different sources. At the same time, it makes possibility of archiving and storing accessed data in e-version in layouts with reflection of data segments, which is most convenient for use in case of any future needs. Remote sensing and GIS technology applications open wide advances in study of dynamic changes of environment condition and design required cases and identification of reasons both positive and negative in data processing stage.

An integration of geotechnical and space technology advances is an excellent instrument in soil environmental studies. Field data is highly important in space technology data processing as the necessary stage of the whole process.

Data Access in GIS Developments for Environmental Studies

Remote Sensing method operates based on detection and analysis of Earth surface features and phenomena using imagery acquired from aircraft and satellites. A GIS is the system for management and display of processed information accessed by Remote Sensing method to be used in decision-making framework. Operational applications of GIS today include such activities as Earth monitoring for diversity aims, land and resources management, traffic planning, marketing, military planning, and a wide variety of other uses. The integration of Remotely Sensed data and GIS for mapping of Land Cover/Land Use option requires a detailed understanding of the ecology, soils, topography, and geomorphology of the study area.

Nowadays various types of Remote Sensing data from satellite, such as MSS, TM, SPOT and AVHRR have been used with GIS for natural resources study, management and development of semiarid areas of the World [2-4].

The fact is that the most expensive and time consuming component of GIS is the updated data access due to the lack of sufficient information selected for study area for the reason of limited store of geotechnical information in electronic format. There are a number of problems even with available information, which needed to be edited, as some of soil features in older maps has to be corrected and specified. Some paper maps can be scanned electronically as raster images, which convert map lines to a series of points and digits. Many GIS applications were formulated to emphasize spatial relationships between mapped objects and such boundaries, where usually represented by a line. The line may be a road, mapped boundary, or some sort of link between two other points of interest. Civil infrastructure elements, such as roads, may not be reflected accurately, in terms of absolute scale, but simply represented by a default line width(s) coded into the mapping software. This condition creates limitation in application mainly in GIS developments especially in dynamic change studies where correct base information is necessary for correlation, comparison of old, and existing situations. It is important to consider these facts in assessment of environmental impacts from variety of sources.

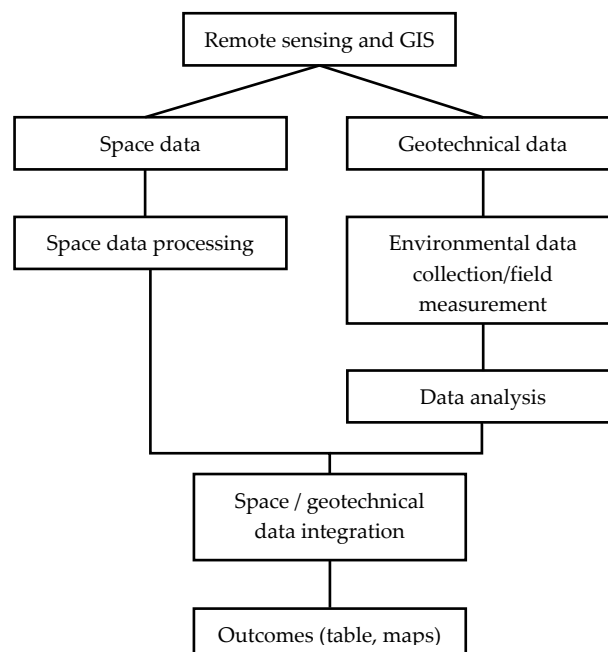


FIGURE 1. GEOTECHNICAL ENVIRONMENTAL DATA PROCESSING WITH SPACE INFORMATION INTEGRATION AND INTERPRETATION.

Remote sensing and GIS technology application is an instrument for appropriate data collection with further processing and integration into GIS in environmental studies. It is important stage of GIS development to start from the segments of data collections based on Remote Sensing method use integration into GIS technology.

A quality of final product in geotechnical investigations depends how correct and right Remote Sensing data shall be used for GIS technology application. The process of interface of Remote Sensing-GIS/Geotechnical environmental investigations has demonstrated in Figure 1. The space image for processing selects after the area for investigation defined. The fact is that the next stage of the method is to collect field data based on geotechnical methods. A samples is needed to be analysed in laboratory and integrated into space data for final processing.

Stages of Data Integration

A GIS makes it possible to mix or integrate information that would otherwise be difficult to associate through other means. These could be soil chemical contamination, physical-mechanical properties in the form of scanned, geo-referenced, and sandwiched with other kinds of data, such as topographic and geologic maps.

Data Structures

Digital geospatial data is collected and stored in many different formats. A GIS must be used to convert data from one type of structure to another. Satellite data can usually be “read” into the GIS in a raster format. Raster data files consist of rows of uniform cells coded according to data values. Computer can manipulate raster files quickly, but they are often less detailed and may be less visually appealing than vector data files. Vector digital data files have been captured as points, lines (a series of point coordinates) or areas (shapes bounded by lines). A typical vector file would be tax assessor’s parcel maps [5, 6].

Data Modelling

A GIS allows to obtain two and three-dimensional characteristics of the Earth’s surface, subsurface or atmosphere from geospatial data. Some common examples of data modeling would be creating isohyets based on different initial information sources. These data models can then be combined with other types of information layers in the GIS [7, 8]. Some common examples would be: combining measured different information sources with elevation, or the thickness of a certain geologic formation (isopach) as compared to the depth to its upper surface (isopleth) where available.

Outcomes

One of the important issues of GIS is its ability to produce pleasing graphics that convey analyses to decision makers and the public at-large. These analyses usually begin with entering any codified restrictions, such as structural setbacks. An attributes included can then be electronically combined and weighted according to arbitrary values set by the body ordering the analysis. Such kind of developed hybrid data in the form of maps frustrate many engineers because they can arbitrarily be weighted to restrict or even eliminate development from areas where the project’s detractors reside on adjacent parcels with all the same attributes.

Geotechnical Field Measurements

Filed measurements in geotechnical investigations are very important in development of GIS technology. During field works boreholes are drilled, samples obtained and field tests performed [9].

For this paper, we selected an area in Sangachal district located on the coast of the Caspian Sea 45 kilometers (28 mi) south of Baku, Azerbaijan. The selected Sangachal Terminal area is an industrial complex consisting of a natural gas processing plant and oil production plan. It is well known and studied during many stages of geotechnical investigations performed previously, therefore there is large amount of data, which can be used for further processing and integration with space data.

Drilling and Sampling

Drilling at the area started immediately after realization of detailed geodetic and topographic investigations. During the drilling process the whole information about the site, depth of boreholes, date, number of samples and soil type were recorded. All possible measures to prevent cores from any kind of disturbance were undertaken. Samples were tightly packed with a suitable material into container and sent to laboratory for further testing.

Standard Penetration Test (SPT)

SPT test is carried out inside the borehole for determination of the resistance of soil at the base of a borehole to the penetration of the split-barrel sampler which is driven dynamically in a standard manner, and obtaining of a disturbed sample for identification purposes.

Soil Electrical Resistivity Test

Soil resistivity is dependent on moisture content and temperature as well as on soil constituents, so that it can vary seasonally and progressively due to the hydrological trends such as changing water tables or continuous drainage.

Laboratory Processing of Field Data

The following tests have been conducted for soil samples collected from investigated area.

Moisture Content

The water content is determined by drying selected moist/wet soil material (the mass of moist soil material is not less than 30g) for at least 18 hours to a constant mass in a drying oven at 105°C up to 110°C. The difference in mass before and after drying is used as the mass of the water in the test material. The mass of material remaining after drying is used as the mass of the solid particles. The ratio of the mass of water to the measured mass of solid particles is the water content of the material.

Particle Size Analysis

Particle size analysis can be performed by means of sieving and/or hydrometer readings. Sieving is carried out for particles that would be retained on a 0.063mm sieve, while additional hydrometer readings may be carried out when a significant fraction of the material passes a 0.063mm sieve.

Maximum Dry Density and Optimum Water Content (Proctor Test)

An indication of the state of compaction of a cohesionless (free-draining) soil is obtained by relating its dry density to its maximum and minimum possible densities (the limiting densities). The tests described in this section enable these parameters to be determined for cohesionless soils.

Determination of Maximum Density of Sands

This test covers the determination of the maximum density to which clean sand can be compacted. Method is suitable for sands containing a small amount of material passing a 63mm test sieve, and up to 10% of fine gravel passing a 6.3mm test sieve. The soil is compacted into a 1 L mould under water using an electric vibrating hammer.

Determination of Maximum Density of Gravelly Soils

This test covers the determination of the maximum density to which gravel or sandy gravel can be compacted. The method is suitable for soils passing the 37.5mm test sieve and containing a small amount of material passing the 63mm test sieve. The soil is compacted into a 152mm diameter CBR mould using an electrical vibrating hammer.

Bulk Density

The bulk density of a soil, $\bar{\rho}$ is the mass per unit volume of the soil deposit including any water it contains. The dry density $\bar{\rho}_d$ is the mass of dry soil contained in a unit volume. Both are expressed in Mg/cm³.

Atterberg Limits

Atterberg limits are determined on soil specimens with a particle size of less than 0.425mm. If necessary, coarser material is removed by dry sieving. The Atterberg limits refer to arbitrarily defined boundaries between the liquid and plastic states (Liquid Limit, w_L), and between the plastic and brittle states (Plastic Limit, w_p) of fine-grained soils. They are expressed as water content, in percent.

Unconsolidated–Undrained Triaxial Compression Test

This test method covers determination of the strength and stress-strain relationship of a cylindrical specimen of either undisturbed or remolded cohesive soil. Specimens are subjected to a confining fluid pressure in a triaxial chamber. No drainage of the specimen is permitted during the test. The specimen is sheared in compression without drainage at a constant rate of axial deformation.

Direct Shear Test

The soil is dried and sieved with 5mm sieve, wetted and placed in the ring of the shear device. Three rings are prepared from one reformed sample, which is placed in the device for preconsolidation. The applied loads varied in range 100kPa to 600kPa, then the box is filled with water or by natural moisture left for consolidation.

One-Dimensional Consolidation Properties of Soils (Oedometer Test)

The oedometer test covers determination of the rate and magnitude of consolidation of a laterally restrained soil specimen, which is axially loaded in increments of constant stress until the excess pore water pressures have dissipated for each increment. Normally, each load increment is maintained for 24 hours.

Key parameter that can be obtained from this test is the preconsolidation pressure $\bar{\rho}_c$. The preconsolidation pressure is estimated using the graphical Casagrande construction. Other parameters that may be derived from this test are the compression index C_c.

Collapse Potential of Soils

This test method covers the determination of the magnitude of one-dimensional collapse that occurs when unsaturated soils are inundated with fluid. Collapse index I_e, percent – relative magnitude of collapse determined at 200 kPa. Collapse potential I_c, percent – relative magnitude of soil collapse determined at any stress level other than 200 kPa.

Determination of Permeability of Soils

The permeability of a soil is a measure of its capacity to allow the flow of water through the pore space between solid particles. The degree of permeability is determined by applying a hydraulic pressure gradient in a sample of saturated soil and measuring the consequent rate of flow. The coefficient of permeability is expressed as a velocity.

Soil Chemical Analysis

Chemical analyses of soil are carried out to determine chloride, sulphate, calcium carbonate content, pH. Soil pH is one of the most common measurements in soil laboratories. It reflects whether a soil is acid, neutral, basic or alkaline. Depending on the amount of sulphate in contact with the concrete, it may be necessary to protect the concrete with a plastic liner, sulphate resistant concrete mix, or a protective adhesive coating.

Table 1 represents the typical values of physical properties of Sangachal Terminal soils.

TABLE 1. SAMPLE GEOTECHNICAL TEST RESULTS FOR SANGACHAL TERMINAL SOILS.

BH No	Sampling interval, m	Moisture content, %	Unit weight, kN/m ³	Atterberg limits			Void Ratio e_0	Max. preconsolidation pressure C_c , kPa	Direct shear	
			γ	Plastic limit: %	Liquid limit: %	Plasticity number: %			Internal friction angle ϕ , deg	Unit cohesion C , kPa
BH-3	5.0-5.3	11.5	20.4				0.478	1006	23.8	79.9
	6.5-6.8	11		24.6	49.7	25.1				
	14.0-14.3	20		27.7	62.3	34.6			21.4	92.8
BH-4	0.0-0.5	14.3								
	7.1-7.5	11.6	20.1	21.9	44.1	22.2	0.495	954	20.5	77.0
	8.5-9.0	11.4								
	11.6-12.0	13		23.4	46.3	22.9			23.0	79.0
BH-5	8.2-8.5	11.0	20.6	23.0	44.1	21.1	0.457	1039	24.1	58.1
	9.7-10.0	12								
	19.2-19.5	22.7	20.0	28.8	63.6	24.8				
BH-6	4.7-5.0	11.5	20.2	24.3	50.7	26.4	0.490	756		
	6.2-6.5	15							24.5	82.5
	17.0-17.3	19.9	20.6	26.2	55.5	29.3			17.8	73.3
BH-7	5.7-6.0	12.4	20.3	23.0	44.3	21.3			23.4	70.1
	15.1-15.6	19.8	20.5	26.9	56.9	30.0				

Data Processing Stage

Figure 2 shows locations of testing points at the area selected for geotechnical investigations (red points). The number of testing locations depends on engineering task and scope of each project. In some cases, it becomes very expensive to carry out huge amount of geotechnical investigations because of the size of area under investigation and number of engineering facilities intended to be constructed.

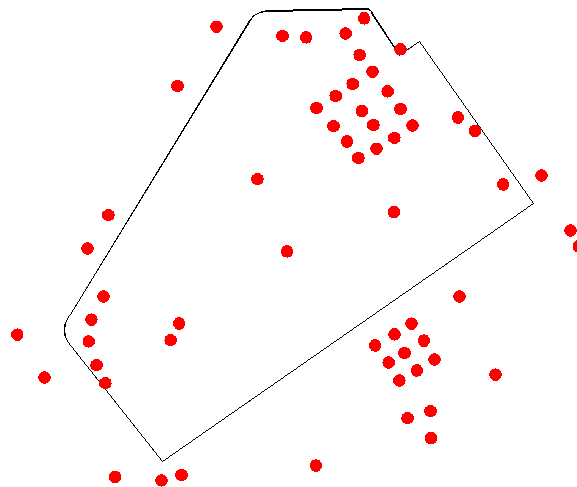


FIGURE 2. SKETCH OF THE SELECTED AREA (SANGACHAL TERMINAL). RED CIRCLES SHOW TESTING LOCATIONS.

It is highly important to define the process of GIS development in geotechnical investigations. Figure 2 describes segments of data collection from different sources and that integration [10].

It has been considered to develop layers for GIS presentation following performance:

- Soil investigations data;
- Chemical contamination;
- Physical and mechanical properties of soil;
- Ground water condition of soil
- Land Use/Land Cover;
- Geodetic and topographic data.

Depending on engineering requirements, more geotechnical data can be integrated into GIS layers. The main available information is tied to various forms of georeferenced information. Accurate merging of topographic map with space image of selected area is required to achieve demanded cartographic corrections. An excellent advantage of GIS is its incorporate processing subroutines that can transform older data to modern coordinates if a sufficient number of georeferencing points can be co-located on both the old and new maps. These georeference points may be presented by established and constructed benchmarks (state or installed), old structures, roads, or even aboveground power lines; anything that can be identified on both maps in the GIS.

Results of data imposed on the space image for selected area are shown in Figure 3. For this picture, space image with spatial resolution of 1m was used. This resolution is high enough for the case of geotechnical studies of selected area.

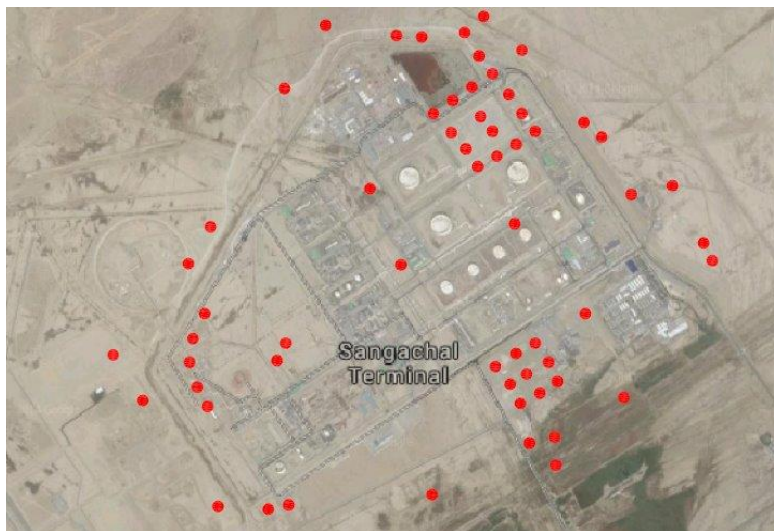


FIGURE 3. INTEGRATION OF GEOTECHNICAL DATA AND PROCESSED SPACE IMAGE DATA.

Conclusions

This paper describes geotechnical investigations carried out at selected area in Absheron peninsula, Azerbaijan. During these investigations, physical and mechanical properties of soils were determined together with soil and groundwater aggressiveness to concrete and metal structures. There is no doubt that it is an excellent source reflecting soil conditions, which can be used for engineering solutions in any stage of implementation: tender package preparation, design and construction.

At the same time integration of geotechnical data into the GIS developed on the base of space data collected by remote sensing method is an advantage of outcomes application in different areas of engineering where suitability and simplicity of data access is required to use (such as project coordination and management, construction, supervision).

In the meantime, the use of data integrated into GIS allows us to link the existing information to the coordinate system, which is very important in all stages of achievements.

Undoubtedly, integration of geotechnical data into space information accessed by means of remote sensing with further development of geographic information system demonstrates variety of use and success in the area. It is not limited only to geotechnical investigations at the selected area for collection of data with purpose of further engineering activities. At the same time, it is the way of solution of different problems, for instance environmental as well as integrating of data into the space information.

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